Patent application

Printing head for squirting out a hot liquid medium and process for the production of a connection point comprising metallic solder

EKRA Eduard Kraft GmbH
Zeppelinstraße 16

74357 BÖNNIGHEIM

1/prts

INS B1

Description

The invention relates to a printing head for squirting out a hot liquid medium according to the preamble of Claim 1, and to a process for the production of a connection point comprising metallic solder according to the preamble of claim 33. The invention furthermore relates to the use of a printing head which works according to the ink-jet printing principle.

The prior art discloses a so-called piezolamellar printing head which is used in an ink-jet printer (Chip 8/94; pages 104-112; "Nur nicht kleckern"). The printing head has a medium chamber for the liquid ink. One wall of the medium chamber is designed as a deflectable diaphragm actuated by an actuator. In the known printing head, the said actuator is designed as a piezoelement which is realized in strip form or as a lamella. The application of an electric voltage causes the piezoelement to change its spatial configuration, as a result of which the diaphragm is deflected. This deflection of the diaphragm reduces the volume of the medium chamber, as a result of which a drop of ink is squirted out from a nozzle or outlet opening. In the known printing head, the ink is initially present in the form of a solid wax crayon which is heated prior to printing, as a result of which the wax crayon assumes liquid form, so that the liquid wax ink can be introduced into the medium chamber, from which it is then sprayed out. In order to liquefy the ink wax, it is heated to approximately 100 to 150°C. The area of application of this known printing head is restricted to ink-jet printing, in which the liquid ink is applied to a paper or a film. In particular, it is not possible to squirt out very hot liquid media, whose temperature may exceed 150°C, ~~using the known printing head.~~

The object of the invention, therefore, is to extend the range of use of printing heads.

This object is achieved by means of a printing head exhibiting the features of claim 1. The printing head according to the invention serves for squirting out a hot liquid medium. It has a medium chamber, one of whose walls is formed by a diaphragm. The diaphragm is in mechanical contact with an actuator, so that the diaphragm can be deflected or driven. The invention provides for the actuator to be thermally decoupled from the diaphragm. In other words, the actuator is technically isolated from the diaphragm in respect of heat and/or cold. This makes it possible for the hot liquid medium to be heated in the medium chamber to a temperature which is necessary to heat a metal or a metal alloy, in particular metallic solder, in such a way that it is present in liquid form in the medium chamber. In a particularly advantageous manner, this hot liquid metallic alloy can then be squirted out by the printing head according to the invention, in order to apply so-called solder deposits to substrates and/or components. By virtue of the fact that the actuator is thermally decoupled from the diaphragm, it can be kept at a working temperature at which its physical properties essentially do not change. In other words - although there may be very hot liquid metal present in the medium chamber - the diaphragm can be driven or deflected very accurately and precisely by the actuator, thereby enabling very hot liquid media of all kinds, in particular highly heated liquid metals, to be squirted out precisely with an accurately defined drop size or volume.

The invention's printing head working according to the ink-jet printing principle thus enables solder deposits, which are also referred to as bumps, to be applied to components or substrates appertaining to microelectronics and/or micromechanics or microsystem technology. Time-consuming and expensive processes have been necessary for this purpose heretofore in order to produce these solder deposits. Solder deposits are required for example in so-called tape automated

bonding (TAB), chip size packaging (CSP) and also in so-called flip-chip connection (FC), as connecting elements between structural parts and substrate. In most cases the solder deposits are present in the form of bumps, eutectic tin-lead or tin-gold alloys, in particular, being used as the solder. The printing head according to the invention now enables these solder deposits to be applied to the components or substrates rapidly, precisely and cost-effectively, in order to produce the solder deposits which are required for the abovementioned connection techniques.

One development of the invention provides for the thermal decoupling to be performed by a thermal barrier element situated between diaphragm and actuator. This thermal barrier element conducts heat poorly, as a result of which the heat present at the diaphragm is essentially not forwarded to the actuator. The thermal barrier element is thus an element which interrupts, or at the very least reduces to a very great extent, the heat transport from the diaphragm to the actuator.

A preferred exemplary embodiment is distinguished by the fact that the actuator is a piezoelement. This piezoelement enables the diaphragm to be driven, that is to say deflected, very accurately, so that a defined drop volume can be ejected from the medium chamber. The fact that the actuator, that is to say the piezoelement, is thermally decoupled from the diaphragm prevents the piezoelement from being bought to a temperature lying above the so-called piezoelectric Curie temperature. Above this temperature, the lattice structure of piezoelectric compounds is cubic. Below this temperature, the structure is distorted, as a result of which distances between the positive and negative charges are shifted, giving rise to an electric dipole moment. In other words: piezoelectric compounds exhibit their piezoelectric effect only when the lattice structure is distorted, so that spontaneous polarization occurs.

Above the piezoelectric Curie temperature, when the lattic structure is cubic, piezoelectricity does not occur in these piezoelectric compounds because an electric dipole moment is not present. Since the printing head according to the invention is equipped with a thermally decoupled piezoelement, the hot liquid medium can thus be present in the medium chamber at a temperature lying above the piezoelectric Curie temperature of the piezomaterial, but the functioning of the piezoelement is not thereby impaired. The thermal decoupling is preferably designed in such a way that the piezoelement is heated to at most from 30 to 50% of the Curie temperature of its piezomaterial, since creeping depolarization can already occur at higher temperatures.

A particularly preferred exemplary embodiment provides for the thermal barrier element to be an integral part of the piezoelement. It is not necessary, therefore, to use a separate structural part for the thermal barrier element. The actuator for the diaphragm can thus be produced easily and cost-effectively.

Particular preference is attached to a piezoelement which has an active and a passive region forming the thermal barrier element, the active region having electrodes for driving the piezoelement and the passive region being designed without electrodes, or the electrodes being present in the passive region but not being electrically conductively connected to the electrodes of the active region. Since the passive region of the piezoelement has no effect for the driving or deflection of the diaphragm, an increase in the temperature of the passive region has no influence on the functioning of the active region. In this case, the length of the passive region is dimensioned in such a way that - proceeding from that end of the actuator which is in mechanical contact with the diaphragm - a temperature gradient in the direction towards the active region occurs in such a way that the temperature at the junction between passive region and active

region is far less than the piezoelectric Curie temperature of the piezomaterial used.

One development of the invention provides for the cross section in the region of the thermal barrier element to be smaller than in the remaining region of the actuator. Consequently, there is a small contact area between diaphragm and thermal barrier element, which contact area reduces the heat transfer. As an alternative or in addition, it may be provided that the thermal barrier element tapers in the direction towards the diaphragm-side end.

In a preferred embodiment, the remaining walls of the medium chamber are formed by a substrate comprising silicon. It may be provided that the substrate is designed like a well, in which case micromechanical structures forming a medium guide within the medium chamber may be present on the inner side of the substrate. Moreover, the micromechanical structures may form a squirting-out opening for the hot liquid medium. The opening in the well-like substrate is thus covered by the diaphragm. A diaphragm made of borosilicate glass or made of silicon is preferably used. The diaphragm is preferably fixed on the substrate edge surrounding the opening in the well. If the diaphragm is present as borosilicate glass, it is preferably fixed to the substrate by anodic bonding. If the diaphragm is present as a silicon diaphragm, the latter is preferably fixed to the substrate by so-called silicon fusion bonding. In general, it holds that the material for the diaphragm is heat-resistant in such a way that the hot medium present in the medium chamber does not damage the diaphragm.

One exemplary embodiment provides for the actuator to be surrounded by a housing. The actuator is thus screened from external influences.

In a preferred embodiment, the actuator is designed as a lamella. It is thus present as a long thin strip whose cross section is significantly smaller than its length. The actuator or lamella extends

between the diaphragm and a housing wall forming an abutment for the actuator. The actuator is thus supported by one of its ends on the diaphragm and is held by its other end in the housing wall, so that force can be transmitted from the actuator to the diaphragm. When the actuator is driven electrically, it expands and contracts, as a result of which its length changes. This change in length thus brings about the deflection of the diaphragm, since its end remote from the diaphragm is fixed to the housing wall. It is preferably provided that the housing wall has a cutout in which the actuator engages with its end remote from the diaphragm. It is preferably provided in this case that the actuator extends through this cutout, so that a contact-making element for the electrodes can be arranged on its free end situated outside the housing. Consequently, the actuator can be connected to an electrical drive arrangement outside the housing, in which case, for the purpose of contact-making or electrically conductive connection, a flexible or rigid printed circuit board is provided which can be plugged onto the contact-making element of the actuator and has a corresponding mating contact-making element.

The housing for the actuator on the one hand forms a protective barrier for the actuator, and on the other hand serves as a supporting body for the actuator, which is fixed by one of its ends to the housing, that is to say to the supporting body.

Particular preference is attached to an exemplary embodiment in which the housing, that is to say, the supporting body, is designed to be electrically insulating and/or to conduct heat poorly. For this purpose, it may be provided that the supporting body is composed of ceramic, preferably zirconium oxide.

A preferred embodiment provides for the diaphragm of the medium chamber to form a wall of the housing for the actuator. In other words: the supporting body or the housing is fitted on the medium

chamber, to be precise in such a way that an opening in the housing is covered by the diaphragm. The housing is thus designed to be open on one side and is closed off by the diaphragm only when it is mounted on the medium chamber. For the connection between medium chamber and housing, thermal decoupling is provided between the two structural parts, so that the heat present at the diaphragm cannot penetrate via the housing to the actuator. The thermal decoupling between medium chamber or diaphragm and the housing is preferably formed by reducing the contact area between the edges of the housing and the diaphragm. By way of example, it is possible in this case for at least one slot to be introduced in the housing wall, which slot is preferably designed to be open at the edge. If a plurality of slots are introduced into the housing, a comb-like structure is preferably present. The contact area between housing and diaphragm is reduced by the slot(s), as a result of which there is little heat transfer from the diaphragm or medium chamber to the housing. In a particularly advantageous manner, the slots provided in the housing also form thermal expansion compensation. In other words, when the housing is heated, it does not warp, as a result of which the actuator is held stably and positionally accurately with regard to its position relative to the diaphragm.

For the connection between diaphragm and housing, provision is preferably made for the side of the diaphragm which faces the housing to be gold-plated, at least in regions, by vapour deposition and sputtering. The supporting body is then preferably designed to be gold-plated with a gold-containing thick-film firing paste at its connection point provided with the diaphragm, so that the connection between diaphragm and supporting body can be produced in a simple manner by means of a gold welding or soldering connection.

One exemplary embodiment provides for the printing head to have a heating device for the medium. As an alternative or in addition it may be provided that the medium is already supplied to the printing head in hot and liquid form. The heating device is preferably designed as a light source, the light source preferably being a halogen lamp. As an alternative or in addition, the heating device may be formed by heating resistors. These heating resistors may be fitted on the substrate forming the medium chamber. The heating resistors are preferably applied to the substrate using thin-film technology, the heating resistors preferably comprising hafnium diboride. The heating resistors can be applied to the substrate by sputtering and be shaped by lithographic patterning.

As an alternative or in addition to the heating device, a cooling device may be provided, which cools in particular the substrate, that is to say parts of the medium chamber. The cooling device is preferably formed by a so-called heat sink, which is preferably designed as a Peltier element.

In a preferred embodiment, the heating device and/or cooling device is assigned to the medium chamber, so that, by means of the heating device, the medium present in the medium chamber can be heated and thus kept in a liquid form. In this case - if this should be necessary - the cooling device can cool the substrate, that is to say parts of the medium chamber.

According to a preferred exemplary embodiment, the heating and/or cooling device is surrounded by a casing which is preferably fixed to that wall of the medium chamber which is opposite the diaphragm. In a preferred embodiment, this wall of the medium chamber forms one wall of the casing for the heating and/or cooling device. The casing is preferably designed to be reflective on the inside and, in a preferred embodiment, is composed of metal and/or a ceramic.

One development of the invention provides for the casing to be thermally decoupled from the

substrate, that is to say from the medium chamber. As an alternative or in addition, the casing may be designed to have poor thermal conductivity. For the thermal decoupling, a layer that conducts heat poorly may be provided between the casing and the substrate.

One exemplary embodiment provides for the medium chamber have at least one, in particular a plurality of squirting-out openings for the hot liquid medium. Preferably, each squirting-out opening is assigned one actuator in each case. Preferably, it is also provided that the medium chamber is present as individual partial medium chambers which are separated from one another, each partial medium chamber having at least one squirting-out opening. Consequently, the squirting-out openings or the partial medium chamber assigned to each squirting-out opening can be activated independently of one another by means of the corresponding actuator.

A particularly preferred exemplary embodiment is distinguished by a protective medium outlet opening, which is preferably directed in such a way that a protective medium emerges in the direction of the squirting-out opening or the squirting-out openings. The protective medium prevents oxidation of the hot liquid medium when the latter emerges from the squirting-out opening, so that it cannot be oxidized by the atmospheric oxygen - until the drop impinges on the connection point to be wetted. An inert gas, in particular nitrogen gas, is preferably used as the protective medium.

One development of the invention provides for the protective medium outlet opening to be designed on the housing of the actuator.

In a preferred embodiment, the housing of the actuator has an inlet opening for the protective medium. The protective medium can thus be introduced into the housing, flow through the latter and then emerge at the protective medium outlet opening, in

order to surround the hot liquid medium drop as protective atmosphere.

Particular preference is attached to an exemplary embodiment in which the inlet opening and the outlet opening for the protective medium are arranged in the housing in such a way that the actuator is situated, at least in regions, in the flow path of the protective medium. In particular, it may be provided in this case that when it enters the housing, the protective medium is at a temperature such that it can serve as a cooling medium for the actuator. The protective medium thus performs a dual function in that, on the one hand, it cools the actuator and, on the other hand, it is used as oxidation protection medium for the hot liquid medium.

Particular preference is attached to an embodiment in which the slot serving for the thermal decoupling between the actuator housing and the medium chamber serves as the protective medium outlet opening. In this refinement, it is advantageous that the protective medium which cools the actuator can also concomitantly cool the housing in the region near the diaphragm, and thus the medium chamber. Heat is thus dissipated from this region, as a result of which the housing is essentially not heated.

One development of the invention provides for a holding plate to be provided for the actuator - within the housing - the said holding plate lying approximately parallel to the diaphragm of the medium chamber. The holding plate is preferably at a short distance from the diaphragm and has, approximately in the centre, a perforation through which the actuator engages with its thermal barrier element. Consequently, the actuator is fixed within the housing - as mentioned above - on one side on the housing wall and, with its other end facing the diaphragm, is held securely in position by the holding plate.

The holding plate is preferably held and guided by means of guide bevels designed on the inside of the

housing. Therefore, the holding plate need not necessarily be fixedly connected to the housing for the actuator. Rather, the bevels on the inside of the housing are designed in such a way that the holding plate is fixed in a defined position. In particular, it is provided that the holding plate is composed of the same material as the housing for the actuator.

One development of the invention provides for the medium chamber to be assigned a temperature-detecting device for the medium temperature. The temperature-detecting device is preferably realized by means of a temperature sensor which detects the temperature of the liquid medium or at least of a wall of the medium chamber. The temperature sensor is preferably realized as a thermoelement or as a thin-film sensor and is preferably fitted to the diaphragm outside the medium chamber.

Further refinements emerge from the subclaims.

The object is also achieved by means of a process for the production of a connection point comprising metallic solder which has the features of Claim 33. The invention provides for the solder to be squirted as hot liquid solder onto the contact-making point of the connection point by means of an apparatus which works according to the ink-jet printing principle. According to the process of the invention, it is possible in a particularly simple manner to apply metallic solder to a contact-making point of a connection point which is provided for connection techniques or connection points in the field of microelectronics and microsystem technology or micromechanics.

In particular, a printing head described above is used for carrying out the process according to the invention.

One development of the process provides for the solder to be squirted out as at least one hot liquid drop from the apparatus.

As it is squirted out, the solder is preferably surrounded by an oxidation protection medium, preferably inert gas. This prevents the hot liquid solder from oxidizing before reaching the contact-making point.

In a preferred exemplary embodiment, the temperature of the hot liquid medium present in the apparatus is detected and monitored. The squirting-out temperature of the medium can thus be set optimally, so that high-quality connection points can be produced.

In a preferred embodiment, pulsed driving serving for squirting out a plurality of drops is provided. If the drops are ejected from a squirting-out opening, it is thus possible for a plurality of drops to be ejected in succession. It goes without saying that it is also possible for the hot liquid medium to be squirted out from a plurality of outlet openings, in which case it is also possible, by way of example, for the partial medium chambers of the individual squirting-out openings to be driven in a manner staggered over time.

In particular, all soft solders from electronic fabrication, which may have a temperature of between 400 and 600°C when being squirted out, may be used as the hot liquid medium. It goes without saying that lead-free solders can also be used. The process according to the invention makes it possible to squirt out individual drops with about 4 pl to 2 nl. Consequently, the connection points produced according to the process can be provided with an accurately defined quantity of solder.

Further refinements emerge from the subclaims.

The invention is explained in more detail below using exemplary embodiments with reference to the drawing, in which:

Figure 1 shows a printing head in sectional side view,

Figure 2 shows a plan view of the printing head of Figure 1,

Figure 3 shows a rear view of the printing head, and

Figure 4 shows a holding and adjusting plate of the printing head.

Figure 1 diagrammatically shows in sectional side view a printing head 1, which works according to the ink-jet printing principle known per se, in other words which can be used to apply a liquid medium from a nozzle 2, also referred to as squirting-out opening, preferably in the form of drops, to a substrate which is to be coated and is at a distance from the nozzle 2.

The printing head 1 illustrated in Figure 1 is constructed modularly and comprises a plurality of modules. In the exemplary embodiment shown, the printing head comprises three modules, namely a so-called printing chip 3, an actuator module 4 and a heating and/or cooling module 5, which is referred to merely as a heating module below. These three modules are separate structural parts which form the printing head 1 by being assembled or connected to one another. Under particular preconditions, the heating module 5 can be dispensed with. However, reference will not be made to this until later.

The base body 6 of the printing chip 3 is preferably produced from a semiconductor base material, for example silicon. The base body 6, which is also referred to as the substrate, forms, together with a diaphragm 7, at least one medium chamber 8. The walls of the medium chamber 8 are thus formed by the substrate 6 and the diaphragm 7, in which case the substrate 6 or the base body - seen in cross section - is designed essentially like a well and the diaphragm 7 covers the opening in the well-like base body 6. Micromechanical structures may be provided on the inner side 9 of the substrate 6, the said structures serving for guiding the medium within the medium chamber 8 and for forming a plurality of partial medium chambers. A further micromechanical structure forms the nozzle 2 of the medium chamber 8.

The diaphragm 7 is preferably produced from borosilicate glass and is connected to the well edges

of the base body 6 preferably by anodic bonding. As an alternative, it is also possible for the diaphragm 7 to be produced from silicon and be connected to the well edges of the base body 6 by so-called silicon fusion bonding. The diaphragm 7 is thus fixedly connected to the base body 6.

The actuator module 4, also referred to as the actuating device, has a housing 10 surrounding an actuator 11. The housing 10 is preferably produced from a material which is not electrically conductive and has poor thermal conductivity. A material is preferably chosen for the housing 10 which has approximately the same thermal expansion coefficient as the material for the actuator 11. For this purpose, by way of example, a ceramic, in particular zirconium oxide, may be provided. The housing 10 does not have a housing wall on its side which faces the diaphragm 7. The opening in the housing 10 is thus covered by the diaphragm 7. For the connection of printing chip 3 and actuator module 4, it is provided that the diaphragm 7 is gold-plated at least in the region of its contact points with the housing 10. The said gold-plating may be applied by vapour deposition or sputtering, for example. If appropriate, at least one so-called adhesion promoter layer may be provided between the gold-plating and the diaphragm. The edges 13 (also see Figure 2) surrounding the opening 12 in the housing 10 are preferably likewise designed to be gold-plated. This can be realized for example using a gold-containing thick-film firing paste. In order to produce the actual connection 14, provision is then made for producing a gold welding or soldering connection between printing chip 3 and actuator module 4.

As mentioned above, the housing 10 surrounds the actuator 11. The actuator 11 is designed as a lamella, that is to say as a long thin strip which is preferably rectangular in cross section. In the exemplary embodiment, the actuator 11 is a piezoelement 15, which extends from the rear side 16 of the housing

as far as the diaphragm 7 and touches the latter. The rear wall 16 of the housing 10 has a perforation 17, through which one end 18 of the actuator 11 engages. With its end 18, the actuator 11 is fixed within the perforation 17, preferably by an adhesive bond. The housing 10 thus forms a supporting element or a supporting body 19 for the actuator 11. Preferably, an extension 20 is additionally provided at the end 18 of the actuator 11, the said extension protruding from the housing 10, that is to say projecting beyond the rear wall 16 of the housing. On its side facing the observer, the extension 20 is provided with an electrical contact-making means 21. It is provided with a further contact-making means, moreover, on the side of the extension 20 which is remote from the observer, that is to say the side which is not visible parallel to the plane of the drawing. Each contact-making means is electrically conductively connected to an activation electrode for the actuator, only the activation electrode 22 which faces the observer being visible. The other activation electrode is parallel to the activation electrode 22 on that side of the lamellar actuator which runs parallel to the plane of the drawing.

At its other end 23, the actuator 11 is mechanically operatively connected to the diaphragm 7. It can be seen from Figure 1 that the actuator 11 or the piezoelement 15 is equipped with activation electrodes only in regions. Consequently, the actuator 11 forms an active part 24 and a passive part 25. On the passive part 25, either no activation electrodes are provided or else the activation electrodes are interrupted at the transition region between active part and passive part, that is to say are not connected electrically to one another. In the exemplary embodiment, the active part 24 of the actuator 11 is designed to be significantly longer than the passive part 25. Proceeding from the rear wall 16, the actuator 11 extends in the direction towards the diaphragm 7

with its active part 24, which is adjoined by its passive part 25, the end 23 of which bears on the diaphragm 7. The passive part 25 forms a thermal barrier element 26, so that heat present at the diaphragm 7 has no influence on the piezoelectrically active part 24 of the actuator 11. Consequently, the actuator 11 or its active part 24 is thermally decoupled from the diaphragm 7. The thermal barrier element 26 is understood to be an element which conducts heat poorly or is at least designed in such a way that the heat present at the diaphragm 7 is forwarded to the active part 24 in a diminished or reduced state. In order to further enhance the poor heat conduction between diaphragm 7 and actuator 11, it is preferably provided that the passive part 25 of the actuator 11 tapers in the direction of the diaphragm 7. Consequently, there is a small area of contact between diaphragm 7 and the actuator or the thermal barrier element 26, which means that there is a small heat transfer area.

In the present exemplary embodiment, the actuator is thus of integral design, in other words the active and passive parts 24 and 25 are produced integrally from the same material.

The housing 10 is preferably thermally decoupled from the diaphragm 7. Little heat flows, therefore, from the diaphragm 7 to the housing 10, so that the heat present at the diaphragm 7 essentially cannot penetrate as far as the rear wall 16 of the housing, the said rear wall serving as an abutment W for the actuator 11. Consequently, the end 18 of the actuator is also thermally decoupled from the diaphragm, any thermal influence of the active part 24 thereby being kept minor. For the thermal decoupling between diaphragm 7 and housing 10, it is provided, in particular, that the edges 13 of the housing 7 have ~~small areas of contact with the diaphragm 7. For this~~ purpose, provision is made, in particular, of a plurality of slots 27 which are designed to be open at

the edge. The slots and the intervening tines 28 thus form a comb structure 29 (Figure 2), so that there are relatively small heat transfer areas 30 between diaphragm 7 and housing 10. The slots 27 preferably extend on the lower housing wall 31 and the upper housing wall 32 of the housing 10. It goes without saying that such slots or comb structures can also be provided on the lateral housing walls 33, on the edges thereof. Proceeding from the edges 13, the slots 27 extend approximately at right angles to the diaphragm. The slots 27 extend only in regions in the housing walls, that is to say not as far as the rear wall 16 of the housing. The supporting body 19 is thus preferably formed in such a way that the slots 27 or comb structures, the perforation 17 and the protective medium inlet opening 43 can be introduced from the front or rear, that is to say there is not need to form lateral openings. As a result, the supporting body 18 can be produced in a very simple manner in a casting mould.

By virtue of the fact that the slots 27 are provided, the housing 10 also has thermal expansion compensation. Although there is thermal decoupling between diaphragm 7 and housing 10 as a result of the small contact areas 30, the housing 10 is nonetheless heated in its region adjacent to the diaphragm. In order to reduce or avoid "warpage" of the housing 10 or of the supporting body 19, the slots 27 serve for thermal expansion compensation. It can be seen from Figure 1, in particular, that the housing walls 31, 32 or 33 taper towards the edges 13.

The heating module 5 is provided on the base body 6 on its side which is remote from the diaphragm 7, the heating module 5 thus faces the well bottom 34 of the base body 6. The heating module 5 comprises a heater source 35, which may be formed by a light source 36. A halogen lamp is preferably used for the light source 36. A metallic medium present in the medium chamber 8 can be heated by means of the heat source 35

in such a way that the said medium is present in the liquid phase, so that it can be ejected from the printing chip 3 through the nozzle 2. In order to increase the efficiency of the heat source 35, it is preferably provided that the heat source 35 is surrounded by a casing 37 closed off by the well bottom 34. A reflective coating 38 is applied on the inside of the casing 37, and reflects the thermal radiation - emanating from the heat source 35 - in the direction of the well bottom 34. Consequently, the heat generated by the heat source 35 is essentially unable to escape from the casing 37. It may also be provided that the casing 37 is produced from a material that conducts heat poorly. For the arrangement of the three modules 3, 4, 5, a series arrangement is chosen, so that the heat source 35 cannot act directly on the actuator 11.

The following method of operation is afforded for the printing head 1:

According to the invention, the printing head 1 is used for squirting out a hot liquid medium which is present such that it is hot and in the liquid phase at least in the medium chamber 8. The activation of the actuator 11 causes the diaphragm 7 to be deflected or flexed in the direction of the well bottom 34, so that the volume of the medium chamber 8 is reduced. As a result, a portion of the hot liquid medium proportional to the reduction in the volume of the medium chamber 8 is forced out of the nozzle 2. Subsequent deactivation of the actuator 11 causes the diaphragm to be withdrawn again from the well bottom 34, as a result of which the hot liquid medium is ejected as a drop from the nozzle 2. The deflection of the diaphragm 7 is achieved by electrical activation of the piezoelement 15. The application of an electric voltage to the activation electrodes causes the lamellar piezoelement 15 to change its spatial configuration. Depending on the polarity with which the activation electrodes are driven, the active part 24 of the piezoelements is lengthened or shortened. Consequently, the diaphragm

can be flexed or bent out or bulged in the direction of the well bottom 34. It is thus clear that the volume in the medium chamber 8 changes as a result of the driving of the actuator 11 or of the piezoelement 15. By means of pulsed driving of the actuator 11, it is thus possible for a plurality of drops of the hot liquid medium to be ejected in succession from the nozzle 2. Depending on the driving frequency, these drops can be squirted out from the nozzle 2 very rapidly one after the other. The extent to which the diaphragm 7 is deflected can be influenced depending on the energy input at the activation electrodes.

In order to keep the volume of the individually ejected drops essentially constant, it is important for the actuator 11 to be kept free of external influences, for example heat or mechanical deformation, so that the diaphragm 7 covers the same path each time it is driven or deflected. In order to keep the inflow of heat to the actuator 11 as small as possible, the thermal barrier element 26 is provided - as mentioned above. In order to reduce mechanical influences on the piezoelement 15, it is the case - as mentioned above that the housing 10 or the supporting body 19 of the actuator 11 is also thermally decoupled from the diaphragm 7 and additionally has the thermal expansion compensation described above.

In order to increase the mechanical stability and alignment of the actuators 11, a so-called adjusting and holding plate 39, which is designed to be essentially C-shaped in cross section, is provided within the housing 10. The adjusting and holding plate, which is designated simply as holding plate 39 below, is guided by bevels 40 on the inside of the housing and is thus aligned exactly. With the free ends of the limbs of the C, the holding plate 39 bears on that side of the diaphragm 7 which faces the housing 10. The holding plate has a perforation 41 approximately centrally in the base of the C, through which perforation the actuator 11 engages by its thermal

barrier element 26. The perforation 41 is dimensioned in such a way that although the actuator 11 is guided, it is not adversely affected when its length changes as a result of the driving of the activation electrodes. The holding plate 39 is preferably produced from the same material as the housing 10.

In a preferred exemplary embodiment, the printing head 1 has a protective medium outlet opening 42, which is oriented in such a way that a protective medium emerging from the protective medium outlet opening flows in the direction of the orifice of the nozzle 2. The protective medium used is preferably a protective medium that prevents oxidation of the hot liquid medium emerging from the nozzle 2, in particular inert gas. Nitrogen gas, for example, may be used as the inert gas. By virtue of the fact that the drop or drops emerging from the nozzle 2 is or are surrounded by a protective atmosphere comprising the protective medium, the drop is prevented from being oxidized during its "flight". This is important particularly when, from the medium chamber 8, as the hot liquid medium, a metallic solder is intended to be applied to a substrate having a connection point. The housing 10 preferably has a protective medium inlet opening 43, which may be present on the rear wall 16 of the housing, for example. The protective medium can be introduced into the housing 10 through the protective medium inlet opening 43, and then flows through the housing 10 before emerging at the protective medium outlet opening 42 in the manner described above. It is provided, in particular, that the protective medium inlet opening 43 and the protective medium outlet opening 42 are arranged on the housing in such a way that the actuator 11, in particular the active part 24 thereof, is situated in the flow path of the protective medium. Consequently, the protective medium also serves as a cooling medium for the actuator. A slot 27 of the comb structure 29 is particularly preferably chosen as the protective medium outlet opening. The flow path for

the protective medium within the housing 10 is particularly preferably chosen in such a way that the protective medium enters at the protective medium inlet opening 43 on the rear wall 16 of the housing, flows around the actuator 11, passes through the perforation 41 on the holding plate, flows through slots 44 on the limbs of the C of the holding plate and thus arrives at the protective medium outlet opening 42. In this case, the slots 44 are preferably congruent with the slots 27 on the housing 10. It goes without saying that a flow path would also be conceivable in which the limbs of the holding plate 39 are designed in such a way that a flow duct which opens in the protective medium outlet opening 42 is present between the guide bevels 40 between holding plate 39 and housing 10.

In the present exemplary embodiment, the medium present in the medium chamber 8, in particular metallic solder, has been heated by means of the heat source 35. It would also be conceivable for the hot liquid medium that is to be squirted out from the medium chamber 8 to be supplied to the medium chamber 8 such that it is already in the liquid phase. If appropriate, the heating module 5 can then be dispensed with.

In order to be able to squirt out very cold liquid media as well using the printing head 1, it is also possible to provide a cooling device assigned to the well bottom 34, for example. For this purpose, a heat sink, in particular a Peltier element, may be provided. It goes without saying that it is also possible to provide both a heat source or heating device and a cooling device or heat sink.

Instead of the light source 36, heating resistors (not illustrated) may also be provided for the heat source 35, the said heating resistors being present on the exterior of the medium chamber 8 on the well bottom 34. These heating resistors are preferably applied to the substrate or the base body 6 using thin-film technology. The heating resistors preferably comprise hafnium diboride.

In order to detect and monitor the medium temperature of the medium present in the medium chamber 8, at least one temperature-detecting element 45 may be provided, in particular on the diaphragm 7, which element is present between diaphragm 7 and holding plate 39, that is to say outside the medium chamber 8.

The at least one temperature-detecting device 45 may be designed for example as a temperature sensor formed by a thermoelement or by a thin-film sensor.

A process for the production of a connection point comprising metallic solder is described below. The connection point has a contact-making point which is also referred to as a contact pad and is intended to be wetted with metallic solder. For this purpose, the above-described printing head 1 is preferably used for squirting out the liquid solder, which may be a tin-lead or tin-gold alloy, for example. It goes without saying that, in particular, all soft solders known from electronic fabrication can be used. The hot liquid solder present in the medium chamber 8 is applied to the contact-making point of the connection point in the form of drops from the nozzle 2 as a result of the deflection of the diaphragm 7. For this purpose, the hot liquid solder present in the medium chamber 8 is squirted out as at least one hot liquid drop from the printing head from the nozzle 2. In order to prevent oxidation of the hot liquid solder drop, the drop is surrounded by an oxidation protection medium ejected from the protective medium outlet opening 2. In order to ensure optimum wetting of the contact-making point of the connection point, the solder temperature within the medium chamber 8 is monitored by means of the temperature-detecting device 45. Consequently, depending on the temperature detected, the heat source 35 can be driven, for example switched on or off, in such a way that the solder is kept at the desired temperature within the medium chamber 8. In particular, the temperature within the medium chamber is kept at

approximately 400 to 600°C for squirting out the hot liquid solder.

Consequently, it is possible in a particular simple and cost-effective manner to simplify connection techniques appertaining to microelectronics, micromechanics or microsystems technology. In particular, tape automated bonding (TAB), chip size packaging (CSP) and, in particular, so-called flip chip connection (FC) can be simplified. In these connection techniques, so-called bumps (solder deposits) are required as connection elements between components and substrate. These solder deposits mainly in the form of bumps can be produced particularly simply using the above-described printing head according to the invention.

In order to produce these solder deposits, it is also possible for a plurality of drops to be ejected from the nozzle 2 one after the other. The pulsed driving of the actuator 11 - as mentioned above - is provided for this purpose, so that the diaphragm 7 can be rapidly moved back and forth, as a result of which the individual drops can be ejected from the nozzle 2.

It goes without saying that it is possible to use a printing head 1 which has a plurality of nozzles 2, in which case it is provided, in particular, that the nozzles are arranged like a matrix. By way of example, a plurality of nozzles 2 may lie in series one behind the other, that is to say in planes parallel to the plane of the drawing. If a multi-nozzle printing head 1 is used, then a plurality of partial medium chambers are preferably provided, each partial medium chamber preferably being assigned at least one nozzle 2. Each partial medium chamber preferably has a separate diaphragm 7, each diaphragm being driven by a respective actuator 11. In other words: all of the nozzles or all of the diaphragms can be driven independently of one another by means of at least one actuator 11 in each case. If a multi-nozzle printing head 1 is used, an arrangement of the actuators as is

illustrated in Figure 2 is preferred. The actuators 11 lie in series next to one another, so that their extensions 20 project next to one another from the rear wall 16 of the housing. In this case, it is provided that the contact-making means 21 are provided on each side of the extension 20, so that contact can be made with the activation electrodes outside the housing. As is evident from Figure 3, the extensions 20 of two adjacent actuators 11 are offset with respect to one another, thereby creating sufficient space for mating contact-making means so that the contact-making means 21 can be electrically conductively connected to the mating contact-making means. Figure 3 also reveals that a plurality of protective medium inlet openings 43 can be provided on the rear wall 16 of the housing. In particular, it may be provided that one medium inlet opening 43 is provided for two actuators 11. It would be conceivable for there to be partitions running within the housing 10 between lower and upper housing walls 31 and 32, the said partitions spatially separating the individual actuators 11 from one another.

Figure 4 illustrates the holding plate 39 in plan view. It is evident that a plurality of slots 44 may be provided on both limbs of the C-shaped holding plate. The slots 44 are introduced into the limbs of the holding plate 39 in such a way that they are preferably congruent with the slots 27 on the housing 10, as is illustrated in Figure 1. It is not absolutely necessary to form the slots 27 on the housing on both the lower and upper housing walls 31 and 32. In particular, it suffices if the slots 27 are present on the lower housing wall 31, in order to form the protective medium outlet openings 42.

A process for the production of a printing head 1 which works according to the ink-jet printing principle and comprises at least the printing chip 3 and the actuator module 4 is also described below. The heating module 5 may be additionally provided. During

production, it is provided that the actuator 11 and the actuator module 4 are connected to one another in a thermally decoupled manner. The printing chip 3 is produced, in particular, as a silicon substrate having micromechanical structures, the micromechanical structures being provided for guiding the medium and for forming a squirting-out opening or nozzle 2. The silicon substrate is preferably designed in the form of a well, the micromechanical structures for guiding the medium being situated on the inner side of the silicon substrate in the form of a well. The nozzle is accordingly designed as an opening from the inner side to the outer side of the silicon substrate. The opening in the well-like silicon substrate is covered by the diaphragm 7 to form the medium chamber 8. In this case, the diaphragm 7 is preferably connected to the silicon substrate by anodic bonding, if the diaphragm 7 is composed of borosilicate glass. If the diaphragm is produced from silicon, the connection between diaphragm 7 and substrate or base body 6 is effected by so-called silicon fusion bonding. During the assembly or connection of the actuator module 4 and printing chip 3, it is preferably the case that firstly the actuator 11 is inserted into the supporting body 19 or housing 10 that holds it, the supporting body then being connected to the diaphragm, to be precise on the side opposite the well opening in the base body 6. For connection between diaphragm 7 and supporting body 19, it is provided that the diaphragm 7 is gold-plated by vapour deposition and sputtering, in particular in the region assigned to the later connection point between diaphragm 7 and housing 10. The edges 13 of the supporting body are preferably likewise gold-plated prior to connection to the diaphragm, a thick-film firing paste having gold being provided for this purpose. The connection between supporting body 19 and diaphragm 7 is preferably effected by a gold welding or soldering connection.

The supporting body 19 or the housing 10 is produced from zirconium oxide preferably in a so-called hot casting process, in which case the perforations 17, slots 27 and guide bevels 40 can be concomitantly formed during the casting operation. As an alternative, treatment or processing is also possible after the sintering of the ceramic in order to form the slots 27, guide bevels 40 and protective medium inlet opening 43.

In order to mount the actuator 11 in the correct position within the supporting body, the abovementioned adjusting and holding plate 39 is used, which is emplaced after the adhesive bonding of the actuator 11 in the perforation 17 over the thermal barrier element 26, so that the thermal barrier element engages through the perforation 41 on the holding plate 39. As the holding plate 39 is being inserted, it is held positionally accurately and securely in the supporting body 19 or housing 10 by means of the guide bevels 40. In this case, the actuator is held between its abutment W on the rear wall 64 of the housing and the holding plate 39 in such a way that its free end 23 can act on the diaphragm, so that the latter can be deflected.

A further production step consists in assigning a temperature sensor to the diaphragm, the said sensor being designed as a thermoelement or thin-film sensor. The temperature sensor is preferably applied to the diaphragm prior to the emplacement of the actuator module 4. The temperature sensor can be produced or formed as a discrete component or using thin-film technology by means of vapour deposition or sputtering and by means of lithographic patterning.

Heating resistors can be applied using thin-film technology on the silicon substrate, in particular on the exterior of the well bottom 34. As resistor material, hafnium diboride is preferably applied by sputtering and formed by subsequent lithographic patterning.

With the above-described printing head 1 which works according to the ink-jet printing principle, it is advantageously possible to extend the area of application of such ink-jet printing heads, so that connection points in microelectronics or micromechanics and microsystems technology can be produced in a simple manner. By way of example, the use of a conventional ink-jet printing head would also be conceivable, provided that the said ink-jet printing head has an actuator element that is insensitive to heat. However, the above-described printing head having an actuator element that is thermally decoupled from the medium chamber is preferably used.